

COMPARISON COPY

Deletions appear as Overstrike text
Additions appear as Underlined text

~~A method and an apparatus for the handling of objects
using a locating system~~

Attorney Docket No. 089537-000000US

Client No. S8435PWOUS

SUBSTITUTE SPECIFICATION**METHOD AND DEVICE FOR HANDLING AN OBJECT
WITH THE AID OF A LOCATION SYSTEM****Background of the Invention**

[0001] The invention relates to a method and to an apparatus for the handling of objects ~~in accordance with the preamble of claim 1 and/or of claim 19.~~

[0002] It is known to use a robot for the handling of objects. A robot having, for example, one gripping arm can be used for the loading and unloading and for the equipping of production apparatuses with workpieces to be processed. The robot can furthermore itself serve for assembly, such as for welding, since a robot arm can be provided with tools and can also carry out complicated manipulations. To move the robot arm in space, linear x, y and z transducers and incremental encoders are provided which are connected to a control computer. However, contamination of the transducers and incremental encoders by water or oil used in production halls and by chips which occur there, can result in operational problems for the robot by which an accurate locating of the robot arm is no longer ensured.

Summary of the Invention

[0003] It is the ~~an~~ present object of the present invention to provide an improved apparatus and an improved method for the handling of objects with which the aforesaid disadvantages are at least very largely eliminated.

[0004] The object is satisfied by the features of the independent claims **disclosed herein**.

[0005] The object is in particular satisfied in that, in a method for the handling of objects in which at least one arm of a handling system for the handling of at least one object is moved in space relative to a reference system, in particular a fixed reference system, the locations of the arms are determined by a locating method with reference to the reference system fixed by the associated locating system.

[0006] The use of the locating method permits a very precise determination of the locations of the arm of the handling system without having to use transducers and incremental encoders which are prone to problems. At the same time, it is possible to steer to points in space much more precisely with the arm. This has the consequence that imprecise manipulations of the arm and - if the handling system is used in production - thus also the generation of rejects can be avoided. The location determination moreover takes place much faster due to the locating method than via the previously used transducers and incremental encoders.

[0007] At least one physical field, in particular an acoustic, optical and/or electromagnetic field, can be set up for the location of the arm. For this purpose, a plurality of transmitters are located in the space around the handling system as field sources of the physical field, for example sources for visible and/or invisible light, whose locations fix the reference system for the locating method. The arm is furthermore provided with at least one sensor for the physical field. Since the propagation speed of the physical field is known, the distance between the transmitters and the arm of the handling system can be precisely determined from the signal transit time. To determine the location of the arm as precisely as possible, it is favorable to

distribute a high number of transmitters in the space. This permits the determination of the location of the arm with an accuracy of approximately up to $\pm 1 \mu\text{m}$. The handling system in accordance with the invention can moreover be set up substantially more easily than known handling apparatuses due to the use of the locating system.

[0008] It is particularly advantageous for a unidirectional locating system, in particular in the manner of the so-called global positioning system, GPS, to be used for the locating of the arm. A one-way distance measurement is carried out in this process by means of the transit time of the signals between the transmitters and corresponding sensors at the arm of the handling system. The measuring error can be kept small in this manner and the determination of the location of the arm can be carried out very precisely.

[0009] In an embodiment, a robot arm can be used as the arm. The advantages presented above can thus also be achieved with industrial robots. This is in particular of importance ~~on the use of~~ **when using** the robot at dangerous workplaces, for example in cooling ponds of nuclear power stations. The method in accordance with the invention and the associated handling system can ~~namely~~ also be used under water since the locating system works reliably under water unlike the linear transducers and incremental encoders of the known systems.

[0010] A gripping arm of a robot which takes up and/or moves the object can be used as the arm. This permits a variety of manipulations of the object so that, in a favorable case, only one robot can take over all necessary manipulations of the object in the space.

[0011] An exchangeable tool or a tool fixedly provided at the arm can furthermore be handled as the object in the space. The method in

accordance with the invention thus permits not only the manipulation of objects, but also their processing, for example assembly and welding work.

[0012] It is advantageous for the relative orientation of the tool to the arm to be determined, in particular independently of the locating system. The operating point of the tool at an object to be worked can thereby be steered to very precisely. If the orientation determination should take place independently of the locating system, at least one sensor, for example a proximity sensor, independent of the physical field of the locating system is arranged in the tool and/or in the arm of the handling system.

[0013] In a further embodiment, the tool can be supplied with energy in a wireless manner, in particular inductively or by means of an accumulator. Control data of the tool can moreover be transmitted in a wireless manner, in particular inductively or by radio. The tool at the arm of the handling system can in this manner be exchanged simply in that a gripping element provided at the arm releases a first tool and takes up another tool, since the tools have an autonomous energy supply and/or an autonomous control.

[0014] It is furthermore of advantage for the locating system to be calibrated by self-calibration. This permits a recalibration of the locating system carried out at short time intervals.

[0015] Further advantageous embodiments of the invention are recited in the following Figure description, and in the drawings ~~and in the dependent claims~~.

[0016] The invention will be described in the following purely by way of example and with reference to the enclosed drawing. ~~There~~

Brief Description of the Drawings

[0017] Fig. 1 is shown:

Fig. 1—a perspective view of an embodiment of an apparatus in accordance with the invention in a schematic representation.

Description of the Preferred Embodiments

[0018] The embodiment of the apparatus in accordance with the invention shown in Fig. 1 includes a robot 10, transmitters 12 distributed in the space around the robot and a control computer 14.

[0019] The robot 10 is mounted on a work table 15 and has a gripping arm 16 at whose free end a grip 18 is provided. The grip 18 serves, on the one hand, to pick up tools 20 from a supply belt 22 and to place them on the work table 15 and to transfer them onto take-away belts 24 after their working. In addition, on the other hand, a tool can be taken up from the tool storage position 26 by the grip 18 and one of the workpieces 20 on the work table can be worked.

[0020] The transmitters 12 are arranged both in the space and on the measuring table 15. They transmit an electromagnetic field, for example a radio signal, in particular a GPS signal.

[0021] A field sensor (not shown here) is provided in or at the grip 18 for the electromagnetic field generated by the transmitters 12. The grip 18 furthermore has a transmitter and receiver element (not shown) which transmits the signals of the transmitters 12 received by the field sensor to a transmitter and receiver module 28 of the control computer 18.

[0022] The tools taken up from the tool storage position 26 have a wireless energy supply (not shown here) and a transmitter and receiver element (likewise not shown) for wireless communication with the control computer 14. Consequently, a tool can be used for the working of the workpiece 20 directly after having been taken up by the grip 18.

[0023] The control computer 14 serves for the processing of the signals of the transmitters 12 and also for the calculation of the control signals for the transmitters 12, for the robot 10 and for the tools from the tool storage position 26. For this purpose, the transmitter and receiver module 28 of the control computer 14 receives the signals of the transmitters 12 and moreover transmits control signals to the transmitters 12, to the robot 10 and to a tool taken up from the tool storage position 26. The transmitter and receiver module 28 moreover receives the signals of the field sensor, which is provided for the detection of the electromagnetic field of the transmitters 12 at the grip 18.

[0024] A proximity sensor, which is independent of the electromagnetic field of the transmitters 12, is provided in the grip 18 for the fine positioning of a tool taken up by the grip 18. The orientation of the tool relative to the grip 18 or to the gripping arm 16 can be measured using this proximity sensor. If the orientation of the tool to the grip arm 16 should not be ideal for a working of the workpiece 20, it can be compensated simply by suitable movements of the gripping arm 16 or of its arm segments. For this purpose, the proximity sensor has a transmitter and receiver element (not shown) which is connected to the transmitter and receiver module 28 of the control computer so that the coordination of the movements of the gripping arm 16 can be carried out by the control computer 14 while taking account of the relative orientation of the tool to the gripping arm 16.

[0025] For the working of a workpiece 20, the first workpiece 20 on the supply belt 22 to be worked is taken up by the grip 18 of the robot 10 and placed on the work table 15. The workpiece 20 is there fixed on the table, for example by an electromagnet. The grip 18 then grips a tool of the storage position 26 which is needed for the desired working of the workpiece 20. Since the tool has its own energy supply and receives independent control

signals, it can be used immediately after the grip has taken it up. The robot 10 now moves its gripping arm 16 to the workpiece 20, while taking account of the relative orientation of the tool to the grip 18, in order to process the workpiece 20 in a suitable manner. After the end of this working step, the tool 20 is transferred by the gripping arm 16, after the gripping arm 16 has again positioned the tool on the tool storage position 26, to one of the take-away belts 24 to then supply the workpiece 20 to a subsequent work step.

[0026] The movements of the gripping arm 16 required for the work step described are controlled by the control computer 14 in that it uses the signals of the transmitters 12 received by the field sensor of the grip 18 for the calculation of the location of the grip 18. The distances between the field sensor and the transmitters 12 are determined from the product of the propagation speed of the electromagnetic field, which is known, and of the transit time of the respective signal. The current locations of the grip 18 relative to the transmitters 12 can thus be determined while the gripping arm 16 is in use. The locations of the gripping arm 18 in space can be determined very precisely in this manner and desired locations can moreover be steered to and set precisely.

[0027] The apparatus in accordance with the invention and the method in accordance with the invention above all permit a determination of the location of the gripping arm 18 or of the grip 16 with a precision of up to $\pm 1 \mu\text{m}$ due to the use of the locating system or of the locating method.

[0028] Alternatively, light sources or sound sources, for example ultrasonic sources, can also be used as transmitters 12 for the electromagnetic field, alone or combined with one another. The field sensors at the gripping arm 16 can then consist of optical or acoustic interferometers which determine phase shifts for the determination of location.

[0029] A field sensor for the electromagnetic field of the transmitters 12 can be provided for the location determination not only in or at the gripping arm 16 and/or in or at the grip 18, but also in the tools of the tool storage position 26.

[0030] The handling system or handling method described can, for example, also be used under water in nuclear power stations.

|

Reference numeral list

10	robot
12	transmitter
14	control computer
15	workpiece
16	gripping arm
18	grip
20	workpiece
22	supply belt
24	take away belt
26	tool storage position
28	transmitter and receiver module